CHAPTER TWO

Laws of Nature and Laws of Physics

The concept of a law of Nature cannot be made sense of without God.

Nancy Cartwright

I had no need of this hypothesis.

Pierre Laplace to Napoleon Bonaparte

IN MANY CONTEMPORARY SCIENCE and religion debates, it is noted that there is some confusion concerning two concepts: the laws of nature and the laws of physics. This is causing serious misunderstanding about the reality of the laws of physics and the actual meaning of scientific laws and theories. It is generally thought that laws of physics represent the actual phenomena which they are describing. This may have been an inherited concept from classical Greek philosophy, since it is known that the word φυσικς (physics) as used by Aristotle means "nature". The word nature means the intrinsic property of something that is capable of causing an effect.[1] On the other hand, the concept of a "law of nature" needs to be clarified so that we can understand its actual meaning, and what it means to be a) natural and b) a law. We can realize the importance of this topic once we understand, for example, the deep philosophical implications of quantum indeterminism and once we know whether that is an objective fact, something which is a reality in the world, or whether it is an artifact of the theory. In cosmology, we need to know whether cosmic inflation is a natural historical cosmic necessity that actually happened during the evolution of the universe—which, if it did, elevates it to the level of being a law of nature—or whether it is just a model that was devised to explain some problems with the big bang theory. A further example is whether we can consider natural selection to be a law of nature for the evolution of living creatures or just a mere suggestion for a possible mechanism, or part of a mechanism, that biological evolution requires. Such questions are indeed of high importance in science and religion debates and in evaluating the content of a scientific theory.

The discussion presented by Paul Davies in his book *The Mind of God* about the "laws of nature" is a typical example of the confusion over laws of nature and laws of physics. Davies sometimes uses the term "laws of nature" to mean what we would describe as natural phenomena, and uses the term "laws of physics" to point to the phenomena themselves. This kind of confusion may lead to absurdities and to the faulty identification of the entities at play when discussing such vital questions as the creation of the universe in a philosophical context. For example, he says that, "given the laws of physics, the universe can create itself".[2] This is a typical example of what I call confusion or misunderstanding by mixing the two concepts into one common meaning. This belief that the laws of physics are descriptions of natural phenomena was the case until the beginning of the twentieth century, when relativity theory came to replace Newtonian mechanics and his law of universal gravitation with more accurate formulations, and when quantum mechanics uncovered the fact that the classical laws of physics were only an approximate formulation of natural phenomena. This confusion might have been brought about by the common origin of the words "nature" and "physics", as both terms historically expressed the same meaning. The confusion causes misunderstanding over the reality of the laws of physics and this leads us to give such laws the status of being in existence "out there" with exaggerated supremacy and sovereignty.

On arguing for the initial conditions of the universe, or the laws operating at initial conditions, Paul Davies suggests that:

> Laws of initial conditions strongly support the Platonic idea that the laws are "out there" transcending the physical universe. It is sometimes argued that the laws of physics came into being with the universe. If that was so, then those laws cannot explain the origin of the universe, because the laws would not exist until the universe existed.[3]

The correct expression for the above paragraph is to say that the laws which are actually "out there" are the laws of nature, for which we do not know with absolute certainty their mathematical construct or the logic behind their operation. These laws of nature came into being with the universe and we do not know how they could have existed before the birth of the universe.

Richard Dawkins is another example of an author who puts forward speculations drawn from Darwin's theory of evolution and tries to present them as being laws of nature. Whereas evolution *is* a law of nature, being an observed fact, Darwin's theory of biological evolution is not. It could be considered to be a law of biology, however. It is not a problem of terminology that I am dealing with here; it is a bit more than that. Thus, I feel the need to clarify the two concepts to enable us to use them in their proper contexts more accurately.

What is a Law of Nature?

A law of nature is a regular phenomenon that occurs once certain conditions are present. We need not know the details of the process that leads to the natural phenomenon, but the phenomenon needs to be repeated with some regularity in order for it to be designated as a law. For example, a stone could fall once dropped from my hand, which is holding it; this is the law of gravity acting naturally. We know that cotton burns once thrown into fire and that vapor condenses once set on a cold surface. We need not know the mechanism by which such a law acts to observe a law of nature at work; for example, we need not know the mechanism by which cotton begins burning, as this will be part of our identification of the factors contributing to this phenomenon and the relation between such factors, which is usually described by the laws of physics and chemistry. History of thought tells us that humans have given different explanations for the same natural phenomena over the ages, depending on their intellectual level and the dominating culture of their age.

Perhaps the earliest of all the laws of nature that man has discovered is the phenomenon of generating fire by hitting two stones against each other. More sophisticated laws of nature were discovered once man had recognized numbers and was able to calculate things. At this point, man started identifying laws of nature which were periodic; for example, the recurrence of solar and lunar eclipses, which is an indication of an order in the universe. This is one of the earliest laws of nature to attract the attention of humans. By observing this phenomenon over a long period of time, the Babylonians were able to identify the periodicity of the occurrence of these eclipses. They found that eclipses come in cycles, each composed of 223 synodic months (29.5306 days each). Eclipses of each cycle recur during the next cycle with a geographical separation of about 116 degrees of arc. Accordingly, the Babylonians were able to tabulate the eclipses of one cycle, which was later called the "saros cycle", and could predict all other eclipses to come. This was one of the earliest discoveries of a law of nature. It is known that the pre-Socratic Greek philosopher Thales of Miletus used this knowledge to resolve a battle between two fighting armies.

More sophistication in recognizing nature was shown when man was able to construct theories from which he could deduce new predictions. Theories were basically proposed in order to explain natural phenomena. That is to say that after man was able to *describe* laws of nature, such as the occurrence of eclipses, he began to *explain* how such laws worked. At this point, *reasoning* started and *causes* were identified for what happened. The early interest of man was directed toward the sky as he wondered how the stars, the Sun, the Moon, and the planets were moving periodically around Earth. Perhaps it was a trivial law of nature to know that Earth should be at the center of all, for everywhere you look you see the sky. According to this model, different celestial objects were located at different distances from Earth according to their observed periods of rotation, measured with reference to the band of fixed stars called the zodiac. The Moon was found to be the fastest with the shortest rotation period of about 27.3 days, so it was placed nearest to Earth; then it was Mercury with a rotation period of 88 days, and next was Venus, which covers the trip in 225 days, and then comes the Sun in the fourth orb, which was observed to cover the zodiac within about 365 days. The red planet Mars was found to cover the zodiac within 680 days and the bright planet Jupiter was known to cover a period of about twelve years. The slowest of all was Saturn, which took about thirty years. Ancient and medieval thinkers, however, considered the celestial orbs of the planets to be thick spheres of rarefied matter, nested one within the other, each one in complete contact with the sphere above it and the sphere below it.[4] And, since it was observed that the stars were fixed and did not change their positions relative to one another, it was argued that they must be located on a single starry sphere called the "sphere of fixed stars".[5] Perhaps the reason why man thought that the celestial objects were fixed in material spheres was to understand why such objects did not fall to Earth, since it was common to see an object fall when set free. Then, in order to explain the apparent motion of these celestial objects within different periods, another metaphysical explanation was introduced where the position of each of these concentric spheres was changed by its own god, an unchanging divine mover which moved its sphere simply by virtue of being loved by it.[6] With such an explanation, man started to construct models for the laws of nature.

What is a Law of Physics?

A law of physics, or a scientific law according to the *Oxford English Dictionary*, is "a theoretical principle deduced from particular facts, applicable to a defined group or class of phenomena, and expressible by the statement that a particular phenomenon always occurs if certain conditions be present".[7]

A law of physics is a well-stated relationship by which parameters affecting the happening of any phenomena are identified clearly in conjunction with other parameters. For example, Newton's law of gravity is a well-stated expression for describing the force of gravity between two masses and the distance separating them. It says that the force of gravity between two bodies of a given mass is directly proportional to the product of those masses and is inversely proportional to the square of the distance between their centers. This statement is a quantitative identification which can be used to calculate the force of gravity between two bodies or more, yet it does not tell us that, once the bodies are set free, they will move toward each other. This needs another law to be effected.

God and the Law

During the seventeenth century, the notion of "laws of nature" crystallized; René Descartes (1596–1650) was perhaps the first in the West[8] to discuss the existence of laws or rules of nature. In his *Principles of Philosophy*, he explained three laws concerning the natural motion of bodies and a conservation rule to conserve the quantity of motion as measured by size multiplied by speed. The claim of conservation, and all the other laws, were grounded explicitly in the activity of a transcendent god on his creation.[9] Descartes had a version of the doctrine of continual re-creation, similar to what the Ashʿaris believed: that the sustainment of the creation is thought to be performed. Daniel Garber[10] tells us that the idea of a law of inanimate nature remained quite distinctively Cartesian throughout much of the seventeenth century. The notion of a law of nature cannot be found, for example, in the works of other reformers of the period, such as Francis Bacon (1561–1626) or Galileo Galilei (1564–1642).

In contrast, Thomas Hobbes (1588–1679) did not think that God had any role to play in natural philosophy. In order to explain how a law of nature worked, he resorted to geometry. The way in which Hobbes interpreted nature through geometry was to say that a body at rest would remain at rest because of a possibility to move in any and all directions; since there is no preferred direction for motion, the body would have to remain at rest. A similar argument applied to a body in constant motion. In fact, this was a rhetorical statement rather than a sound scientific argument. This kind of understanding is obviously denying the need for an agent to activate such events.

The geometrical argument is similar to saying that a free stone falls on the ground just because there is a gravitational force between the stone and the earth. But here we are ignoring the question of how gravity works. If you are a free, rational thinker, you would ask such questions, but, if you would like to ignore them, you could always attribute the action of gravity to another cause: the existence of mass according to Newton or the presence of a curvature of spacetime according to Einstein. Hobbes denied divine intervention, as he could not visualize how something non-physical could affect the physical. This we can see in the following paragraph:

> The subject of [natural] Philosophy, or the matter it treats of, is every body of which we can conceive any generation, and which we may, by any consideration thereof, compare with other bodies, or which is capable of composition and resolution; that is to say, every body of whose generation or properties we can have any knowledge . . . Therefore, where there is no generation or property, there is no philosophy. Therefore it excludes Theology, I mean the doctrine of God, eternal, ingenerable, incomprehensible, and in whom there is nothing neither to divide nor compound, nor any generation to be conceived.[11]

Most of the efforts in science are directed toward knowing *how* nature works rather than knowing *why* nature is behaving like this or that. For this reason, and in the absence of sensible answers to the questions "how?" and "why?", it would be reasonable to adopt the empiricists' view that there is no law of nature, otherwise the laws of nature cannot be made sense of without God. In fact, the question of how a non-physical entity could affect a physical entity is one of the challenging questions at present in science and religion debates.

The modern sciences, mainly physics and biology, have weakened belief in God by assuming that the universe can be explained by a collection of laws that can be expressed in logical or mathematical forms. This eventually means that the universe is logically intelligible on the basis of deterministic causality. Classical celestial mechanics, for example, have verified this deterministic causality to the extent that they allowed Pierre Laplace (1749–1827) to claim that, once the initial conditions for any system are known, one can predict all subsequent developments of the system without the need to invoke the intervention of the divine; he says:

> We ought to regard the present state of the universe as the effect of its antecedent state and as the cause of the state that is to follow. An intelligence knowing *all* the forces acting in nature at a given instant, as well as the momentary positions of *all* things in the universe, would be able to comprehend in one single formula the motions of the largest bodies as well as the lightest atoms in the world, provided that its intellect were sufficiently powerful to subject *all* data to analysis; to it nothing would be uncertain, the future as well as the past would be present to its eyes. The perfection that the human mind has been able to give to astronomy affords but a feeble outline of such intelligence.[12]

The view that the world is developing independently of the notion of God culminated later in the declaration by Friedrich Nietzsche (1844–1900) that God is dead. This same belief in deterministic causality may have motivated Albert Einstein to ask whether God had any choice in creating the universe.

The proper scientific investigation of the world started with considering facts of nature as being empirical outcomes of experiments and observations. In this trend, which started with Galileo, the scientific quest to understand the world adopted the principle of seeking explanations for its phenomena by identifying their *natural* causes. Galileo realized that a proper investigation should concentrate on discovering the actual variables involved in the natural behavior of the world and finding the relations between these variables. He studied the motion of freely falling bodies, the swing of a pendulum, and then looked at the sky using his simple telescope. He achieved great discoveries in every track that he followed. This experience enabled him and the generations that followed to obtain a new insight into the world by which mankind was transformed into the age of modern science, the "proper science". The Galilean revolution did not come out from nowhere all of a sudden; the history of thought tells us that there were many previous advances in the methodology of the scientific quest that had paved the way for such a consideration.

The real transformation in the history of science and the physical law came with Sir Isaac Newton, who had studied the works of Galileo and realized the value of symbolizing variables and understood the implications of generalizing the formulations obtained from experiments and observations. Sir Isaac Newton (1642–1727) formulated the three laws of motion and the law of universal gravitation. Newton was an abstract thinker who invented differential calculus, by which he contributed a great deal to the advancement of science and humanity. Despite subscribing to personal religious beliefs, Newton did not include any metaphysical assumptions in his laws. The one comment he made about readjustment of the comet orbs was a remark rather than a serious scientific position. Newton declared that "religion and Philosophy are to be preserved distinct. We are not to introduce divine revelations into Philosophy, nor philosophical opinions into religion".[13] I find that the Newtonian approach to science and religion is the best option that one can adopt where a person subscribes to a religious belief. Science, being in one's intellectual background, may help to refine personal beliefs and inspire greater confidence based on rational attitudes rather than dogma.

After Newton, more sophistication was achieved in formulating the laws of motion and the law of universal gravitation. These refinements and upgrades were brought in by Laplace, Lagrange, Poisson, Euler, and many others who constructed classical mechanics. The laws of classical physics formulated as such were deterministic, as the associated natural phenomena belong to the macroscopic world, which seems to follow deterministic causal relationships. This trend served as inspiration for the thinkers of the eighteenth-century Enlightenment. Consequently, the Enlightenment philosophers subjected religion to an unprecedented rational scrutiny, many of them rejecting Christianity for deism and a few even turning to atheism.

The Laws of Modern Physics

The modern physics of the twentieth century probed the natural world at the microscopic level. New concepts were introduced and a new logic had to be generated. The part was no longer necessarily smaller than the whole, nor did the particle have to be a highly localized entity. The character of the physical law took a sharp turn at the beginning of the twentieth century toward abstraction. Mathematical formulations became more and more representative of the physical system. This allowed for a broadened scope of interpretations and controversy on explaining the implications of the laws of physics. For example, the introduction of wave–particle duality by Louis de Broglie brought in Heisenberg's uncertainty principle and the probabilistic character of the natural phenomena. In essence, laws of nature turned out to be indeterministic, whereas the laws of physics remained deterministic.

There are some aspects of the laws of physics that cannot correlate with the laws of nature, for example, time reversal. This is something that is exclusively assigned to some fundamental laws of physics, but not to the laws of nature. Time reversal does not actually take place in nature because it would contradict the second law of thermodynamics. Time reversal mainly arises in those physical laws which contain a second derivative with respect to time. An example of this is the Maxwell equations of electromagnetism. Another example of a physical law that exhibits time reversal is the Klein–Gordon equation, which is an equation of motion describing the behavior of particles moving at very high velocities (relativistic particles). If the physical law is a first-order differential equation in both space and time, then time reversibility can be achieved in conjugation with space and, if the particle is charged, then it might be possible to have the physical law exhibiting charge conjugation, time reversibility, and space inversion. This is called CPT (Charge conjugation, Parity, Time reversal) symmetry. For some time, particle physicists were fascinated by CPT symmetry, as it seemed to help solve some problems, but later such high hopes proved to be exaggerated. Nature is consistent and will never contradict itself. Consequently, one can say that time reversibility is an artifact of our mathematical formulation.

A good law of physics in my opinion is one with rich content, one that is simple and economical, and elegant in form. Elegance may include some sort of symmetry. An example of this is Einstein's field equation, where we have the whole of spacetime and its material content being expressed in one compact form composed of three terms, two on the left-hand side describing the geometry of spacetime and the third on the right describing the matter–energy content. This form can be decomposed into sixteen second-order partial differential equations (PDEs) describing the gravitational field on one side as a curved four-dimentional spacetime composed of three spatial dimensions and one time dimension. We are all familiar with curved surfaces like the surface of a ball, for example, but we are not accustomed to thinking about curved time. It is rather beautiful to see how time curves when we decompose the Einstein field equations. This is what popular science writers call "time warp". The Dirac equation is another example of a physical law that enjoys richness, simplicity, and elegance. This is a first-order partial differential equation written in a compact form using matrices. Originally, it was invented to describe the state of the electron, which is why Dirac called it the "equation of the electron", but later it was discovered that the same equation describes positrons too. Changing the mass in the equation allows it to describe the proton, neutron, neutrinos, and all spin-½ particles. The Dirac equation can be decomposed into four separate equations, two of them describing an electron with negative and positive energy states, and the other two describing a positron with positive and negative energy states. The Dirac equation is perhaps the most beautiful law of physics, although it is not the richest.

The power of a scientific theory is mainly embodied in its ability to generate verifiable predictions. A theory which can only explain phenomena is still useful, but certainly is considered to be at a lower level in the hierarchy of scientific theories. This surely applies to theories of physics. It is through the practical verifications of its theoretical predictions that we know that a theory is correct, or that it at least presents a better description of the world than its predecessors. Relativity theory, for example, contains all the predictions of Newtonian mechanics and his law of gravity plus several other predictions which have been verified by direct and indirect observations. This is what makes Einstein's theory of relativity superior to Newton's theory.

One other important characteristic of a scientific theory is that it must be consistent. This means that it should not be possible to use the assumptions of a theory to reach conclusions that contradict its other results. Results obtained from a theory should be unique and, if different versions of the same theory were to be discovered, then this would result in a lack of confidence.

This happened with string theory, for example, which, although it gained much popularity, could not provide verifiable predictions despite its basic simplicity and elegance. Five string theories were found, not one (later interpreted to be five versions of one and the same theory). However, this remains a controversial question.[14]

A theory should not depend on many undefined parameters. For example, the theory of cosmic inflation was devised in order to remedy some serious loopholes in the standard big bang theory of the origin and development of the early universe, but it could not specify a well-defined potential for driving the proposed inflation, which is a fundamental parameter. This problem was counted as one of the shortcomings of the cosmic inflation theory. One more example is the standard model of elementary particles, where the values of the masses are not well known, they are only set by hand. This, we hope, will be rectified in order to have a consistent and complete theory for particle physics.

Science has now become the accumulation of consistent knowledge that has two very important properties. The first is the capability of self-correction and the second is the property of correspondence by which new theories converge with those they replace, producing the same results once set to the special conditions described by the old theory or physical law. For example, Einstein's general relativity has provided us with a law of gravity that replaced Newton's law of universal gravitation. However, the law provided by Einstein reduces to the same expression as Newton's law of gravity in the case of weak gravitational field. Therefore, Newton's gravity becomes a special case of Einstein's gravity. This same property applies to quantum mechanics, where we find that the laws of quantum mechanics reduce to the corresponding laws of classical mechanics once the action (energy multiplied by time or distance multiplied by momentum) of the physical system becomes much larger than the value of Planck's constant.

At this moment in history, physics is in crisis. There are many unsolved problems and, toward the end of the twentieth century, the theories of physics became more and more speculative. Mathematical machines produced many abstract speculations with poor physical content and very few verifiable profiles. Most important is the quantum measurement problem, which has found no resolution and is hindering the advancement of quantum physics. In addition, there are problems concerning the unification of quantum mechanics and gravity. Because gravity is being described by a non-linear theory, there seems to be no way of unifying it with the linear theory of quantum mechanics. To understand gravity at the quantum level, it is necessary to understand the beginning of the universe and the singularity at the center of the black hole, and several other situations.

We also encounter problems associated with the standard model of cosmology: the big bang model. Some of the problems have been solved by suggesting the era of cosmic inflation, but some physicists believe that the inflation hypothesis itself is suffering from fundamental theoretical problems. Some other non-inflationary models have been suggested too, but mainstream research in cosmology still follows the big bang model.

Our description of the world remains approximate as long as we are in this world, and in no way can we dream of obtaining an absolute theory in the near future. This fact of life, which we encounter every time we go into deep analysis of our scientific knowledge, pushes us to believe in an extrapolated case where an omnipotent and omniscient agent has to exist for this universe to be. It might be that some people would not agree with the notion of God as represented by the main religions; however, a belief in the necessity of an omnipotent and omniscient agent for the universe to exist does not necessarily mean that we should believe in the God defined by religions. On the other hand, the scientific quest need not refer to the action of such an agent in any detailed description of causation or explanation of events in nature. It remains a matter of personal or communal belief how to account for the role of an omnipotent and omniscient agent.

Logic, Mathematics, and Reality

Away from the standard definitions, and in a simple word, I can describe "logic" as being a collection of basic axioms deduced from known first principles that constitute a set of rules for reasoning and deduction. The most direct and simple logical rule says that the whole is larger than its parts. On identifying the parts of a whole, we are identifying countable entities which belong to the whole. This kind of identification is made possible by the characteristics of our natural world. Computability of the parts is a fundamental characteristic of the world which makes it possible to construct counting machines, which may have started with the Babylonian mathematical tables that were in use a long time ago. Perhaps it is for this reason that the Oxford mathematical physicist David Deutsch considers computability to be an empirical property which depends on the way the world happens to be rather than on some necessary logical truth:

> The reason why we find it possible to construct, say, electronic calculators, and indeed why we can perform mental arithmetic, cannot be found in mathematics and logic. The reason is that the laws of physics happen to permit the existence of physical models for the operation of arithmetic such as addition, subtraction and multiplication. If they did not, these familiar operations would be non-computable functions.[15]

Here again, I may point out that Deutsch should have used the term "laws of nature" instead of "laws of physics", since it is the laws of nature that are allowing such a computability and not the laws of physics. This is one more example of a physicist and mathematician misusing terms.

This kind of understanding of computability helps one realize why we are able to comprehend the world as a computable and physical system, a world which is explicable in terms of numbers and reasons. This is where the laws of nature and the laws of physics meet; it is in the arena of mathematics that we can describe the physical world most accurately. This is perhaps what made Galileo realize that the world is written in the language of mathematics. It is through the laws of physics that we realize the world is reasonable, comprehensible, and, to some extent, predictable. It is true to say that, "there is evidently a crucial *concordance* between, on the one hand, the laws of physics and, on the other hand, the computability of the mathematical functions that describe *those same laws*".[16] But, it is not true to say that the nature of the laws of physics permits certain mathematical operations to be computable—such as addition and multiplication—for, if it were so, then the laws of mathematics would be a subset of the laws of physics, whereas in fact it is the other way around. Plato's mathematical forms were transcendent; how could it be so unless the laws of mathematics enjoy a kind of superiority over the laws of physics? It is more likely that it is the laws of nature which permit certain mathematical operations, and not the laws of physics.

Babylonians where known to have developed a mathematical system that enabled them to solve numerical equations of the third order. They were able to calculate many parameters of nature, such as the length of the year, taken from different reference points and with very high accuracy. The invention of the sexagesimal system was a great help to Babylonian astronomers and mathematicians, who used the system very efficiently and were able to obtain their results with very high accuracy. Otto Neugebauer, the Austrian-American mathematician and historian of science, described the Babylonian computational efficiency with the following words:

> The system of tables alone, as it existed in 1800 B.C. would put the Babylonians ahead of all numerical computers in antiquity. Between 350 and 400 A.D. Theon Alexandrinus wrote pages of explanations in his commentaries to Ptolemy's sexagesimal computations in the Almagest. A scribe of the administration of an estate of a Babylonian temple 2000 years before Theon would have rightly wondered about so many words for such a simple technique.[17]

Many of the theorems of geometry and geometrical relations were known to Babylonians and, according to Neugebauer, "the Pythagorean theorem was known to the Babylonians more than a thousand years before Pythagoras".[18]

Mathematical systems can be very helpful not only in obtaining accurate prescriptive results, but also in exposing the secrets of the laws of nature. For example, tensor calculus greatly helped Einstein in formulating gravity as a spacetime curvature, by which Einstein was able to recognize Newton's law of gravity as only an approximate formula, making its use suitable for only weak gravitational fields. Tensor calculus enabled Einstein to recognize that the gravitational field in a four-dimensional spacetime has ten components rather than one. This is a fascinating example of the revealing power of mathematical systems. Vector calculus enabled James Clark Maxwell to formulate his electromagnetic theory in a neat and vivid form.

These examples make one feel that mathematics does have its version of reality. The fact that tensor calculus can help me to uncover that a gravitational field has more components than believed as I describe it in a linear vector form is astonishing. However, mathematics cannot stand alone as a tool to probe nature. Physics is also needed to provide us with insight into the underlying meaning and content of mathematical formulations. Mathematics cannot identify on its own the axes of a coordinate system, let alone label such coordinates for describing spacetime, for example. Mathematics is a machine that is able to generate new expressions for describing relationships between symbols satisfying a certain set of axioms and conditions. A good mathematician is someone who can drive this machine efficiently. It is the physicist who identifies those symbols and uses them to describe variables of physical systems. In doing so, he then can deduce the relations between those variables and, accordingly, discover the related physical law. The beauty of mathematics appears when we obtain general solutions for our physical problem, by which we describe the problem in its mathematical form. Then come physical conditions, which are normally introduced to the general mathematical solution as boundary conditions, to assign the physical limits imposed by the real situation specified by the problem.

Here the fundamental question arises: is it physical law that is embodied in mathematics or is it mathematics that is embodied in the natural phenomena (the laws of nature)? One can ask this question in another way: can we say that mathematics is the underlying structure of the world? Many examples can be provided in support of an affirmative answer. On the other hand, there are many consistent mathematical laws which find no place in natural phenomena. It is not possible to explain the world on the basis of mathematical consistency alone, as there are many consistent mathematical forms that do not find a place in the real world. Steven Weinberg was puzzled by this and considered it a dilemma that atheism is suffering from.[19] In addition, one may say that the world of mathematics is quite open to any development and that it is unlimited, except by the required consistency. Indeed, this is where the natural world meets with the world of mathematics. This might sound like Platonic philosophy of course, but it is the result of any free critical thinking. How, then, can we get Weinberg out of the fix he finds himself in? The answer might be somewhere in the distant future, as we have not yet discovered everything in the world. Mathematics, I gather, is the language of the world, but it is physical assumptions that might lead mathematics to acquire meaningful expression, or likewise to produce nonsense. This means that the extent of mathematics as a venture is as broad as the world is open, and not the other way round. The world is designed in such a way that allows mathematically solvable formulae to describe it in a consistent way, and that is what we call the "laws of physics".

However, as the world is so open, to the extent that we do not even know its limits, we cannot say for sure to what degree of conformity our mathematical formulation would comply with the reality of the natural world (the laws of nature). For this reason, it would be reasonable to assume that many of our mathematical formulations which are now thought to be redundant might find their way into certain future applications by which they could represent some states of the natural world. For example, we now deal mostly with what we call a "time-like world" in which physical causality in the conventional chronological order of cause and effect applies, but there is no reason why a different kind of world, a space-like world in which the chronological order of cause and effect is reversed, should not exist. Such a world may exist within the same space and time in which we are living; it is only another region of the spacetime. In fact, the spacetime diagrams invented by Herman Minkowski contain such regions and the theory of general relativity accommodates such a space-like world. This kind of space-like universe is not well understood yet, but it is said that the spacetime inside the event horizon of a black hole is space-like. The laws of physics are basically the same with only some physical quantities having interchangeable roles, such as space and time, and in these cases changes are measured according to variations of space, not variations of time. This means that the status of things may not change as time passes, but would change as we changed places. That is why different trajectories (so-called "geodesics") in a space-like universe would have different destinies and fates. A space-like world is a new world that we are not accustomed to; nevertheless, it is an alternative to our world. Some of the laws of physics would not change when going to a space-like universe, but some other laws may. For example, Maxwell's laws of electromagnetism would not change, but the electric and magnetic charges would exchange roles. We would not be able to see a single electric charge (electric monopole), but instead we would be accustomed to seeing the magnetic monopoles. Were we to move from our time-like world into a space-like world, we would find that the laws of nature have changed even if some laws of physics remain the same.

In the light of the above discussion, we can firmly conclude that mathematics obtains its realistic status through the laws of physics and that the laws of physics are constructed to express the relations between the parameters which contribute to natural phenomena. The laws of nature thus allow for the employment of mathematical constructions to describe them, at least in an approximate form following our own comprehension, and this is what makes these laws describe an approximate reality on the technical level. But, on the conceptual level, no ultimate truth can ever be claimed, no matter how long science is in progress. The good thing is that we are on the right track; every day we improve our calculations and refine our concepts about the laws of nature, but no ultimate status can be reached as long as there is time. Therefore, the dream of an ultimate theory for everything is far-fetched.

Conservation Laws

Conservation laws are the most important safeguards for the consistency of our physical world. These are the main pillars of physics without which no physical world can be comprehended. If there were no conservation laws then we would not be sure of anything, our physics would be vague, and the world would be running miraculously. The fact that some physical quantities are known to be conserved in natural processes makes us confident of the validity of physics. This is why Descartes placed so much emphasis on the importance of conservation law. However, no conservation law is known to be absolute. The conservation of physical quantities is known to apply within certain limits.

Despite the suggestion of conservation laws being made by Descartes and Leibniz as early as the seventeenth century, the deep implications of the notion were not well established until the late 1930s. When it was discovered in the early thirties that the neutron disintegrated into a proton plus and an electron, it was found that the total mass energy of these two particles did not add up to the total mass energy of a neutron. So, Niels Bohr proposed that the conservation of energy might, on average, only be working statistically.[20] However, it was later suggested that another particle is released during the disintegration of the neutron. But, since the electric charge is conserved, and because the neutron has zero charge, the proton has a +1 charge and the electron has −1 charge; therefore, the suggested particle should be neutral. It was called the "neutrino". The story of the discovery of the neutrino is one of the fascinating pieces in the history of modern physics. This discovery reveals many evidences of the success of theoretical physics, which consolidate the fact that this universe is ruled according to certain laws which are based on rigorous logic. The exciting part is the discovery that the neutrino must have a spin-½, which makes it a member of the family of fermions. This was achieved with full reliance on the law of conservation of spin angular momentum. The fuel of the Sun was only discovered with the help of the law of conservation of mass-energy without which the huge energy radiated by the Sun could not be explained.

It is fascinating to know that conservation laws are profoundly related to the symmetry of physical systems. Symmetry is known to mean equality, so when we say, for example, that the human body is symmetrical with respect to right and left, it means that every feature of our right side resembles the corresponding feature of our left side. When we say that an unmarked ball is symmetrical when rotating around any axis passing through its center, we mean that it remains the same at any angle during such rotations. But, once we mark the surface of the ball with scars, then it will not retain the same symmetry. The scars will cause a break in the symmetry. Similarly, an unmarked square is symmetrical under rotation by 90 degrees about an axis passing through its center, but a marked one will not have the same symmetrical properties. Here again, the mark causes a break in the symmetry. All symmetries correspond to certain conservation laws and many conservation laws in elementary particle physics were discovered through studying their symmetry groups.

Light preserves the symmetry of the spacetime it moves through. According to the theory of general relativity, time becomes dilated near massive bodies owing to the bending of time that is caused by gravity. This might be understood as if the light, while moving through spacetime, makes units of distance along its path (the wavelength) larger and larger as it approaches the massive body in order to keep the pace at a constant value. This implies that light (and all electromagnetic radiation) is a property of spacetime; it is the unit by which space and time is measured simultaneously. Accordingly, the speed of light in a vacuum must be constant with respect to all other observers, because otherwise the invariance of spacetime will be lost and, consequently, each point in space or time will have its own physics. Therefore, one can say that the constancy of the velocity of light is the most fundamental law of nature.

Why Should There Be a Law?

Why should the world behave in a way that is comprehensible through mathematics and the laws of physics? The laws of nature (the recurrence of natural phenomena) are clear evidence of an ordered world. But why *should* there be law and order in the universe? In fact, we do not know the origin of the laws of nature, which we describe by the laws of physics; we do not know why the world follows such laws unless we adopt a teleological explanation. This is what provoked Albert Einstein to say that "the most incomprehensible thing about the universe is that it is comprehensible".[21] So, it is we human beings with our advanced consciousness who are giving the world its meaning. But why is a teleological explanation not welcomed by many scientists?

Suppose we live in a world that does not seem to follow any set of laws. We might call such a world "chaotic". However, I am not intending to discuss chaos here, which might be described by highly non-linear laws. Instead, what I mean is a world in which some things are produced suddenly and may disappear suddenly too; a world without any fixed measure or rules and without any regularity. Such a world would not be productive and no material construct could be seen in it. The fact that we are here with such a complex composition is sufficient evidence for the existence of law and order in our world. But does this mean that our existence becomes inevitable, given the laws of physics? Can the laws of physics stand as sufficient cause for our existence? This is by no means a trivial argument. It could be accepted that the laws of physics become sufficient cause for our existence if we can prove that these laws have the power, intelligence, planning, and hindsight to act and produce the results they are acting for. But, which of these laws or sets of laws has the character that would qualify it for such a status? One might say that such a question will be answered once we discover the so-called "theory of everything", that we will discover the mother of all laws of physics, which can explain everything in one shot. But would such a law then belong to the laws of physics? If so, then it would have to have the fundamental characteristics of those laws, among which is the inherent inaccuracy in describing the world, and in this case it would not qualify as the ultimate answer. Otherwise, such a law would have to transcend all of our knowledge and, as such, it would not belong to the realm of physics. On the other hand, mathematically Gödel's incompleteness theorem prevents us from obtaining an absolute, complete proof from any set of axioms. Therefore, if an ultimate law were to exist, it would have to be something that could transcend our mathematics as well as our physics. In fact, this is the essential stumbling block in the atheistic argument for a universe with sufficient cause ascribed to any law of physics at all. In a letter to Solovine, Einstein wrote:

> You find it strange that I consider the comprehensibility of the world (to the extent that we are authorized to speak of such comprehensibility) as a miracle or as an eternal mystery. Well, a priori, one should expect a chaotic world, which cannot be grasped by the mind in any way . . . the kind of order created by Newton's theory of gravitation, for example, is wholly different. Even if a man proposes the axioms of the theory, the success of such a project presupposes a high degree of ordering of the objective world, and this could not be expected a priori. That is the "miracle" which is constantly reinforced as our knowledge expands.[22]

The above questions and analysis lead us to conclude that, no matter how our theories are refined, the ultimate reality cannot be comprehended without resorting to some super, transcendental power that has the will and knowledge to produce such a magnificent world. Such a power might not be a personal being, as described by the holy scriptures of religion, but it would certainly have to enjoy independence from our physical world. If not independent of the world, such a power would have to be either a part or the whole of the world. Accordingly, this power would have to abide by the laws of the world, which would then bring such a superior power to a lower status and restrict it from being able to control the world. This is the reason why Spinoza's god is not valid.

The Cosmological Argument

The cosmological argument ascribes the creation of the universe and all its contents to a supernatural agent: God. Among these is the Kalām Cosmological Argument, which was recently reformulated by William Craig. On the contrary, it is argued that the laws of physics provide enough reasons for the existence of the universe without the need to refer to any supernatural agent. Stephen Hawking[23] and, more recently, Lawrence Krauss[24] have spread such a claim in their popular books written for laymen. The main argument is based on the assumption that vacuum quantum fluctuations, the so-called "virtual states", can be turned spontaneously into real matter and energy, that is to say, real states. This can only be achieved if an external field of force existed, which would enable virtual states of the vacuum to be converted into real states. In a real situation, the field of force would have to be strong enough to achieve such an operation. The question is, from where can such a field of force be produced if we have nothing? Stephen Hawking argued that it could be the force of gravity. But how can a strong field of gravity be produced in a vacuum? No way, since the vacuum fluctuations could only produce a feeble force that would not be strong enough to convert virtual states into real ones. Consequently, a spontaneous generation of real states out of a vacuum is deemed to be impossible.

On the other hand, and through a somewhat philosophical argument, given the fact that vacuum fluctuations are a contingency, they are therefore certainly subjects of the initiation and sustainment that keep such virtual states popping up and down within a time duration below Heisenberg's uncertainty limit. Who, then, would do that and what kind of a law would work to sustain the state of the quantum vacuum? What kind of law governed the initial conditions of the universe before it came into being? Certainly neither Hawking nor Krauss, nor any other physicist, can answer such a question. This point will be discussed further below.

The Cosmic Singularity

On discussing the beginning and the fate of the universe, it is usually claimed that cosmic singularity is unavoidable.[25] Usually, this claim is supported by a reference to the work of Roger Penrose and Stephen Hawking[26] in which they proved a theorem which shows that, in the classic general theory of relativity, cosmic singularity is unavoidable. But, this misses the fact that, in that work of Penrose and Hawking, quantum effects were ignored and therefore such a result cannot be confirmed as representing the actual conditions for the beginning or the fate of the universe. In fact, in discussing this matter, some physicists claim that once space has infinitely shrunk, it must literally disappear and consequently time and matter will disappear too. This claim is not well established in detailed physical terms, since we need a full theory of quantum gravity in order to provide the mechanism for the big crunch or the big bang. To date, such a theory is not available. An alternative detailed mechanism, which might be more realistic, is provided by what I have called the "non-singular quantum model of the early universe".[27] In this model, matter is produced from the vacuum energy that is produced by the unfolding of the curvature of spacetime. So, practically, we start at the moment when a highly curved spacetime existed, producing intense Casimir energy out of the vacuum fluctuations; this energy was converted into matter through the era of matter generation (where massive particles are produced by a condensing of the energy, maybe through the mechanism of a Bose–Einstein condensate, which takes place at very high temperatures). At this moment, the first matter was born and the first law of the interaction of matter with radiation was set at work. In this model, the material content of the universe is generated gradually out of an unfolding of the spacetime curvature which was given a priori, not in one shot as stipulated by the standard big bang model.

For this reason, we have no singularity at the beginning of the universe. Some details of the model need to be worked out further in order to understand the full details of the mechanism of matter generation and the conversion of energy into massive particles. This model is free from all the known problems that are associated with the standard big bang model and, therefore, needs no inflation era to remedy those problems.

Laws of Physics at the First Moment

All physicists agree that the laws of physics ceased to work at the first moment of existence of the universe. The problem of the initial conditions for the birth of the universe is one of the stumbling blocks in gaining a full understanding of the universe's very early moments. Great minds like those of Penrose, Hawking, Hartle, Wheeler, and many others have been concerned with this problem, but no conclusive answer has been obtained. Whereas all the laws of physics just ceased, the laws of nature were at work. This is because the laws of nature were controlling the actions that were occurring. It is because of this that I say that the laws of physics are what we know about events and processes taking place in this world, but the laws of nature are those which might be unknown to us and yet are still at work. This humble understanding of the world is what we may all adopt in order to avoid the blindness of dogma and the arrogance that dominates thinking at times.

It is true that our understanding of the laws of physics is an approach to our understanding of the laws of nature, but at all times our understanding and formulations remain limited by our mental capabilities and comprehension. We cannot claim at any point that we have reached the ultimate understanding of anything at all in the world, so how can we be so confident that we can deny the existence of other agents at work? One thing we have to show in any argument is the logical sequence of reason. Arguments referring to a supernatural agent as being the reason for what happens in nature are not scientific arguments because they cannot explain the events. A supernatural agent is part of a person's beliefs and cannot be proved to exist until one's comprehension adjusts to accommodate facts within a certain framework. However, if one were to attempt to understand this existence and to appreciate such a level of consciousness and comprehension, it would make sense to consider an extended sort of world which goes beyond what we know through conventional logical arguments that adopt cause and effect and employ material existence as the only means of deduction. When we go beyond this kind of logic, we can transcend into a form of logic that allows for other versions of comprehension to be realized. However, here we need to be careful not to fall into the fallacy of illusion. When we go beyond our standard logic and comprehension into a transcendent state, we should always have a connection to our formal logic and rational comprehension, yet we should be free from the materialistic dogma which captivates us inside the horizon of a physical world. So, a subtle balance is needed for a factual understanding of the world as a whole and a humble comprehension that allows for other factors to be at play, to seek a comprehensive picture of what is at work. This might be an approach that achieves Einstein's dream to "catch God at work".[28]

Given the main attributes of God, it is not difficult to realize that He cannot be considered part of the world. A Spinoza type of god, to which Einstein had subscribed, is an extrapolation of the cosmic law and order. This could only be the case if there were a coordinating power within the cosmos itself, a far-fetched requirement to be part of our physical world. Therefore, it seems that in no way can we escape transcendence if we are to seek an explanation for the existence and development of the world.

So why should we seek to prove the existence of God simply through the laws of physics, which are part of our comprehension of the world, and ignore the fact that the world goes beyond our knowledge? Is this not what we cultivate by contemplating the events of this world? Is it not this that we learn from the development of scientific thought through the ages? We cannot disprove the existence of God by tracing what we know of the laws of physics. But can we prove the existence of God otherwise? The blunt answer is no, for God is an entity that goes beyond our standard logic; therefore, it is hard to see how we can, using such arguments. However, once the world is assumed to be His creation, we can always contemplate it and reflect on the attributes of God in an approach to comprehend Him as best as we can. This is how we can approach God and seek His company. But, again, it is a matter of faith and submission.

The laws of physics are deterministic, for example the Schrödinger equation, whereas the laws of nature are probabilistic. We cannot predict the occurrence of any phenomenon with absolute certainty; this is the outcome of quantum physics by which deterministic causality is invalidated. The reason why the laws of physics are deterministic is because they are formulated on the basis of mathematical logic, which has no room for indeterminism. However, indeterminism does not rule out causality, it rules out deterministic causality.

The Mind of God

A final question is whether the laws of physics that we are devising or discovering reflect the mind of God? The answer might be obtained when we answer the question of whether scientific theories express facts and realities or whether they are expressions of our own minds and imaginations? Theories suggest expressions for the laws of physics to expose quantitative relationships between variables. However, some philosophers like Nancy Cartwright think that these laws might sometimes lie.[29] She asserts the fact that, despite the explanatory power of theoretical laws, these laws do not describe reality. Indeed it is the case and this is exactly one major difference between a law of nature and the corresponding descriptive law of physics.

The history of modern science tells us that scientific theories change over time and, although a correspondence is established sometimes between the results of calculations based on new theories and the old ones, it is found that the concepts are liable to change. We now have two famous and well-studied examples: quantum theory versus classical radiation physics, and relativity theory versus Newtonian mechanics and gravitational theory. We have seen how the classical particle concept has changed and how the wave–particle duality concept replaced the old one and constitutes the substratum of quantum theory. Moreover, the determinism of classical physics was replaced by the indeterminism of quantum systems. These new concepts completely changed the philosophy of a law of nature. A deterministic world may not need God if the laws operate independently, but an indeterministic world would surely need an external agent to decide the results and coordinate the actions of different, sometimes conflicting, laws. A universe abiding by deterministic laws can enforce a kind of self-ruling; the entire universe can run in a self-contained manner. On the contrary, if indeterminism underlies the structure of the laws of nature, then surely the need for an external ruler becomes inevitable. That is why Einstein could not accept the notion that God plays dice.[30] Here, reason conflicts with nature, which does not necessarily follow the laws that our minds have devised, but follows the laws that were devised by the Creator.

The laws of physics by which we describe natural events are actually devised by our minds, the mind of Paul Davies for example, but not by the "mind of God". So, in one way or another, we are discovering the human mind and its workings and not how the mind of God works. This fact may easily be recognized once we remember that people thought for more than 200 years that Newton's law of gravity was the law of God controlling the solar system. Then it turned out that neither the mathematical formulation of Newton's law nor his concept of gravity were right, despite the fact that astronomers successfully used it to calculate the orbits of the planets in the sky precisely, and even to predict the existence of other planets which were duly discovered later. That is why no one can catch God at work, not even the great Einstein himself.[31]

Different conflicting and stand-alone laws cannot act by themselves to produce the organizational qualities or the delicacy of nature. These laws need some coordinating mechanism, which would be, in essence, yet another law of nature. Otherwise we have to resort to an external agent that does not abide by the characteristics of nature itself. In no way can we find a single law unifying all the laws in nature, simply because such a law would contain the mechanism and control necessary for the coordination of all the other laws; that is a self-defeating goal, because such a goal, in replicating itself ad infinitum, must ever elude us. Therefore, the role of an external agent that does not follow nature is deemed necessary to resolve such a dilemma, an agent that acts outside of space and time and does not necessarily abide by our logic and comprehension.

Physicists and other scientists need to revise the ways they think about God in order to be able to seriously comprehend the possibility of having an external power, will, or wisdom, or whatever initiates, controls, and sustains the universe. God needs to be thought of as an abstract entity that exists and acts beyond physical space and time. Otherwise, if we think of God as an entity within and as part of our physical world, and characterize Him according to our scientific standards, then we surely will be "led to conclude that adding God would just make things more complicated, and this hypothesis should be rejected by scientific standards", as Sean Carroll puts it.[32] God is not physical; were it so, He would be contained within the universe. He would then be subject to the laws of the universe and would need a supernatural power to coordinate His acts and sustain His will and power.

In one important paper,[33] the philosopher of science Nancy Cartwright has argued that the concept of a law of nature cannot be made sense of without God. Cartwright did not mean to defend a theistic view, rather she argues that assuming that laws of nature are prescriptive and not merely descriptive, and supposing that the laws that are responsible for what occurs in nature, would require God. Cartwright suggests an alternative by which the order of nature can be maintained without immediate reliance on God by accepting the proposal of empiricism. Nothing in the empirical world makes anything happen, rather nature is a collection of events one after another. In this vision, there is still a realization of the regularities among these events and recognition of the causal relationships, nevertheless Cartwright points out that there is no way in which these laws can be said to govern events in nature. This vision is based on the Hume's teachings. In one version of the views, the blue-blood empiricism, some regularities are thought to necessarily hold.

This view echoes the original ideas of al-Ghazālī concerning his rejection of the presence of a deterministic causality. Indeed, al-Ghazālī saw the regularity of events occurring in nature as being a sort of "custom", explaining that these laws are written in the book of nature and, as Cartwright asserts, "there is no sense in which they can be responsible for what happens".[34] Cartwright concludes that, without God, God's plans, and God's will, there can be no laws of nature for an empiricist.

In the next chapter, I will discuss the question of the laws of nature from an Islamic point of view under the subject of causality, where I will show how some Muslims, namely the *mutakallimūn*, understood causal relationships in the world and the action of the Creator in sustaining the world.